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RESPONSES OF ZEA MAYS PRODUCTIVITY TO INTERACTIVE EFFECTS OF TILLAGE OPERATIONS AND WHEAT STRAW MULCH UNDER AN ARID ENVIRONMENT FOR AGRICULTURAL POLICY MEASURES

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ABSTRACT

Synchronizing the production function, a study was chalked out with the hypothesis to quantify the effects of various tillage practices and rates of wheat straw on the productivity of maize crop in existing arid environmental conditions. It has been amazingly found that tillage practices caused appreciable increase in plant height, biological yield, thousand grain weight and grain production compared to zero tillage practices. The hydraulic conductivity increased, while bulk density decreased under various tillage operations. However, hydraulic conductivity and bulk density parameters were little influenced by various rates of mulch. The organic matter content, nitrogen, phosphorus and potassium median contents were less affected by various tillage practices, however, significantly affected by addition of various biomass of wheat straw mulch. The various tillage operations produced non-significant ($P > 0.05$) effects on nitrogen and potassium median content in shoot tissues, while phosphorus median content were affected significantly. In shoot tissues, application of mulch did not produce significant ($P < 0.05$) impact on assimilates of higher quantity of nitrogen, phosphorus and potassium concentration in shoot tissues.

KEYWORDS: Tillage Operation, Productivity, Mulching, Maize and Environment

INTRODUCTION

Maize (Zea mays L.) ranks at third position among most important cereal crops after wheat and revel in terms of area and production around the globe. In Pakistan, maize crop covered an area of 974 thousands hectare with production of 3707 thousand tones (Agricultural Statistics of Pakistan, 2010-2011). During the last decade, the prices of farm inputs, i.e. seed, fertilizer, pesticides / weedicides, fuel and irrigation were arisen substantially, whereas the productivity of crop is lower than average potential level. In the era of climate change, the natural resources are depleting rapidly. Researchers have calculated that even a fractional increase in temperature, (0.5 oC) would result in yield reduction by 10-15%. Moreover, historically available water at farm gate has reduced by 50-60%.

The continuous change in weather conditions, reduction in available water and land resource and more importantly high inflationary phenomenon occurring in farm input prices call for more conjunctive and integrated management agronomic practices to enhance productivity of cereal maize crop. Different researchers (Pervaiz, *et al.,* 2009) have reported that conservation of soil moisture by adoption of appropriate tillage operations with concurrent use of plant residue as mulching resulted in sustaining the productivity of crops. Rathore, *et al.,* (1998) found greater quantity of soil

moisture under straw mulched area compared to untreated check, which resulted in higher grain yield of chick peas. Application of crop residue mulches improves fertility status with respect to organic matter content (Panstin, *et al.,* 1977; Havlin, *et al.,* 1990).

The different tillage operations performed according to soil conditions, specific crops and agro-ecological environments contributed towards improving physical conditions for proper growth and development of crops (Rasmussen, 1999). The fertility status has improved substantially and high tillage operations are carried out at proper soil moisture conditions (Rice and Smith, 1982; McKenny, *et al.,* 1993; Khurshied, *et al.,* 2006; Pervaiz, *et al.,* 2009) Moreover, sustained crop production is greatly substantiated by conservation of soil moisture under low –rainfall environments (Unger, *et al.,* 1991; Ullah, *et al.,* 2009 and Rahmatullah, *et al.,* 2012). Various researchers (Lal, 1995; Unger, 1986; Wicks, *et al.,* 1991) have reported 10-15% increase in grain yield of maize crops grown on fields prepared by different preparatory and tillage operations. At the advent of climate change, and global warming, the present field study was under taken to quantify the effects of different tillage operations in conjunction with straw mulch on productivity of maize crop under an arid environment.

MATERIALS AND METHODS

A field study was undertaken at the experimental farm of Institute of Soil and Environmental Sciences, University of Agricultural, Faisalabad. The composite soil samples were taken (consisting of 10 cores) before imposition of treatments. The soil samples were analyzed for the physical and chemical characteristics of soils (Table 1). The treatments were consisted of (i) different tillage operations: (a) zero tillage: direct drilling without disturbing soil: (b) conventional tillage: three ploughing with narrow tine cultivator followed by planking with wooden planker; (c) deep tillage: One chiseling at 30 to 40 cm depth with three shovel spaced at 45 cm followed by narrow time cultivator and planking with wooden planker; (ii) rates of mulch: 0,2,4,6 Mg ha-1. The layout of the experiment was split plot design, having tillage operations (main plot) and rates of mulch (sub-plot) with three replications.

The ridger was used to make ridges for sowing purpose. The differential quantities of mulch in the form of wheat straw were spread after complete germination of maize sown on 20th July and harvested on 22nd October, 2008. Crop was planted plant with 70 cm row-to-row distance. The recommended rates of nitrogen (250 kg ha-1), phosphorus (250 kg ha-1) and potassium (125 kg ha-1) in the form ofurea, diamnonium phosphate and potassium sulphate were applied, respectively. The whole quantity of phosphorus and potassium was applied at the time of sowing. While nitrogen was applied in 3- splits, i.e. one-third each at sowing, 30 days after germination and tasseling stage, respectively.

The pre-emergence weedicide were used to control weed infestation. The composite soil samples (consisting of 20 cores) were collected randomly up to 0-15cm depth. Soil samples were analyzed for pH by pH Meter (McLean, 1982); electrical conductivity of soil extract by Rhoades (1982); soil texture by Bouyoucos Hydrometer Method (Moodie, *et al.,* 2001); soil moisture by gravimetric method (Jolota *et al.,* 1998); soil bulk density by core method (Blake and Hartage, 1986). Hydrantee conductivity and soil organic matter by Walkey and Black (1934) method; total nitrogen by Bremer and Mulvancy (1982); available phosphorus by Olsen and Sommers (1982) and available potassium by Richards (1954) Data on plant height and total dry matter yield production (at 15% moisture) were collected after harvesting of crop. The grain yield production (at 15% moisture) was recorded at maturity and was analyzed for nitrogen, phosphorus and potassium in shoots parts of plant. The soil samples were removed after harvest of crop from each experimental unit and analyzed for fertility parameters (organic matter, nitrogen, phosphorus, potassium) and physical parameters (bulk density and hydraulic

conductivity). Total nitrogen was determined by sulphuric salicylic acid digestion method (Buresh, *et al.,* 1982) and total phosphorus and potassium by method of (Chapman and Pratt, 1961).

The planned experiment had been laid out in Split Plot Design having tillage operations, (Main plot) and rates of mulch (Sub-plots) which were replicated thrice. All the requisite data recorded through experimentation had been analysed statistically and their means were compared by least significant differences at α 5% level of confidence. All the statistical analyses were performed by using Stat View 5.0 (Steel, *et al.,* 1997).

RESULTS AND DISCUSSIONS

Growth and Development

In this context plant height differed significantly ($P < 0.05$) due to interactive effects of tillage practices and different quantities of straw mulch at maturity (Table 2). Crop maintained maximum plant height of 208.0 cm under deep tilled conditions compared to 186.9 cm under zero tillage. Crop attained plant height of 203.7 cm under treatment receiving 6.0 Mg ha-1 wheat straw mulch compared to 197.5 cm under untreated check. The combined effect of deep tillage operation and mulching at the rate of 4.0 mg ha-1 resulted in producing of plant height of 212.3 cm compared to 204.0 cm under conventional tillage. The results of this study coincides the findings of various scientists(Bionari, *et al.,* 1994; Alburquerque, *et al.,* 2001) that plant height has been enhanced by improved soil structure, aeration and greater retensi of moisture in root zone through different tillage operations. Pertaining to this, Pervaiz, *et al.,* (2009) reported that maize crop flourished well under deep tilled soil and receiving 14.0 Mg ha-1 straw mulch.

Biological Yield

It is evident from data that dry matter yield production at maturity differed significantly ($P < 0.05$) due to combined effects of different tillage practices and quantities of wheat mulch applied. Tillage increase biological yield significantly ($P < 0.05$) and maximum biological yield (28.8 Mg ha-1) was recorded in deep tillage and minimum (16.3 Mg ha-1) in zero tillage treatment (Table 2). the biological yield was enhanced significantly by spreading different quantities of straw muleh. Maximum (26.1 Mg h-1 biological yield was obtained by spreading of 6.0 Mg ha-1 straw mulch compared to minimum (18.9 Mg ha-1) under untreated check. The highest quantity of dry matter yield (34.5 Mg h-1) was obtained by interactive effects of deep tillage with addition of 6.0 Mg ha-1 wheat straw mulch. There results were similarto those of (Diaz-Zorita, 2000) that biological yield of maize crop was enhanced substantially by ploughing the soil to deep level and mulching for greater conservation of soil moisture and reducing the weed infestation during the growth period.

Grain Yield

It is the linchpin for the farming community in all their socio-economic factors. In this regard thousand grain Weight differed significantly due to tillage system and quantity of mulch and their interaction also (Table 3a). Maximum thousand grain weight (758.3g) was recorded compared to minimum (710.6g) under zero tillage treatment. The addition of straw mulch at the rate of 4.0 Mg ha-1 resulted in attaining higher thousand grain weight (758.2g) compared and 696.3 produced by untreated check. The conjunctive use of deep tillage and spreading of 6.0 Mg ha-1 wheat straw mulch resulted in production of highest thousand grain weight compared to untreated check. Data for grain yield differed significantly because of different tillage operations and spreading of differential biomass of wheat straw mulch. The highest grain yield (10.52 Mg h-1) was produced under deep tilled compound to zero tillage operation. Furthermore, spreading of straw mulch

at the rate of 16.0 Mg ha-1 caused producing of higher grain yield (10.41 Mg h-1) compared to untreated check. Bonari, *et al.,* (1994) and Pervaize, *et al.,* (2009) reported that grain yield is significantly higher with deep ploughing compared to conventional seed preparation. Moreover, various researchers (Liu, *et al.,* 2002) reported that mulching leads to higher grain yield because of greater availability of soil moisture, better nutrients availability and particularly controlling weed infestation. Hence, the increased productivity resulted due to better grain filling and higher grain weight achieved under conducive environments for growth and development.

Soil Bulk Density

This attribute is imperative for tillage operation to achieve the maximum yield by the end user. It has been amazingly noticed that bulk density was significantly ($P < 0.05$) affected because of tillage operation and was non-significantly ($P > 0.05$) influenced by different biomass of mulch. Bulk density was higher (1.29 Mg cm-1) under zero tillage followed by conventional and deep tillage operations. Various researches (Diaz–Zorita, 2000; Khurshid, *et al.,* 2006) reported that bulk density was significantly decreased by enhancing tillage practices (Table 4a). On the other hand, bulk density was little affected due to spreading of different quantities of mulch. The results of this study are contrary to the findings of Ghuman, *et al.,* (2001), that bulk density of the plough layer was reduced by mulching. However, the bulk density was reduced to minimum (1.05Mg m-3) level by combined effect of deep ploughing and arid application of mulch at the rate of 6.0 Mg ha-1.

Hydraulic Conductivity

This segment has been pointed out as an essential fate for the irrigation dogma. Pertaining to this, it has been strongly shown by the data that hydraulic conductivity was significantly ($P < 0.05$) affected due to different tillage operations and was non-significant ($P > 0.05$) due to different rates of wheat straw mulch (Table 4). Maximum value of hydraulic conductivity (3.14 x 10-4 cm s-1) was recorded under deep tillage operations followed by conventional and zero tillage treatments. There was little difference among different mulch treatments. The hydraulic conductivity was improved substantially by conjunctive adoption of conventional tillage and spreading mulch at the rate of 6.0 Mg ha-1. The results of this study are contrary to those of Lal, *et al.,* (1978) that hydraulic conductivity could differ because of application of various quantities of mulch.

Soil Organic Matter Content

Soil organic matter is a sole proprietorship for the existing soil fertility index. In this consortium the data for organic matter was significantly ($P< 0.05$) affected by spreading of different quantities of much, but was influenced a little by tillage operations (Table 5a). The addition of wheat straw at the rate of 4.0 to 6.0 Mg ha-1 resulted in the buildup of organic matter compared to farming practice. The different tillage operations had no affect on buildup of organic matter. However, the conventional tillage practices combined with application of 6.0 Mg h-1 wheat straw resulted in higher quantity of organic matter compared to deep tillage operations. Different researchers (Lal, *et al.,* 1980; Khurshid, *et al.,* 2006) reported that organic matter was significantly ($P < 0.05$) improved by application of mulch in conjunction with conventional tillage practices. The values of organic matter were enhanced due to mineralization of added mulch under aerated conditions.

Nitrogen, Phosphorus and Potash Content in Soil

Being a structural element, Nitrogen has a prime importance for growth and development attributes of test crop. For this purpose the data for nitrogen content in soil differed significantly (P < 0.05) due to application of wheat straw mulch, however, in significantly differed among tillage operations (Table 5b). It is evident from the data that the tillage operations did not improve the Nitrogen median content in soil column. The similar results have been reported by Ji, *et al.,* (1998), who found no significant effects on nitrogen content in soil. The mulching produced profound effects on increasing nitrogen content, with simultaneously increasing levels in organic matter in soil. The highest values of nitrogen content (1.30%) was recorded by addition of 6.0Mg ha-1 wheat straw compared to 0.58% under untreated check. The results are in line with those of Halvin, *et al.,* (1990) who reported increased nitrogen content due to greater quantity of organic matter by addition of mulch. Regarding to Phosphorus content in soil, the data showed statistically significance (P < 0.05) by different tillage operations and addition of various biomass of mulch (Table 5c). The more median contents of phosphorus (12.96mg kg-1) were present under deep tillage compared to conventional and zero tillage. The addition of 6.0 Mg ha-1 wheat straw mulch resulted in raising the level of phosphorus median content from 10.81 to 13.94mg kg-1 under deep tillage practice. The values of phosphorus content also improved by combined effect of tillage operation and mulching (Table 5d). Halvin, *et al.,* (1990) found that fertility status of soil is improved by mulching and has not enhanced a significant quantum of potassium in soil.

Nitrogen, Phosphorus and Potash Content in Plants

The median content of nitrogen in shoot tissues because of tillage operations and various quantities of mulch and interactions of these two treatments were non-significantly (P > 0.05) affected under maize production system (Table 6a). The results differ with other researchers (Acharya and Sharma, 1994) that mulched treatments generally significant (P < 0.05) greates maintenance of nitrogen median content in maize shoot tissues than corresponding un mulched ones. Pertaining to phosphorus median content in shoot tissues of maize were significantly (P < 0.05) affected by tillage operations and mulching as code as due to their combined effects (Table 6b). Averaged across different rates of mulch, crop grown on deep tilled soil maintained higher concentration (0.12%) of phosphorus in the shoot tissues followed by conventional and zero tillage treatments. Averaged across tillage practices, the application of 6.0 Mg ha-1 wheat straw raised phosphorus median content by 62.5 % over the untreated check. The level of phosphorous concentration was raised to 75% because combined effects of deep tillage and addition of 6.0 Mg ha-1 wheat straw over untreated check (0.08%). These results agree with those of Acharya and Sharma, (1994) and Pervaiz, *et al.,* (2009) who reported individually or combined adoption of tillage practices and mulching had profound effect on maintenance of higher phosphorus concentration in maize shoot tissues. While considering the median content of potassium in shoot tissues, it was non-significantly (P>0.05) affected by individual or combined effects of different tillage operations and doses mulching in maize production system (Table 6c). Averaged across rated of mulch, values of K median content in shoot tissues were 2.44%, 2.42 %, 2.41 % in crop grown on deep, conventional and zero tillage practices, respectively . Averaged across tillage practices, the maximum value of K concentration in shoot tissues was 2.44 % under 6.0 Mg ha-1 straw mulch compared to 2.40% under untreated check. On the other hand other researchers (Acharya and Sharma, 1994; Pervaiz, *et al.,* 2009) found that mulching in the median cintent with different tillage did influence on maintaining higher median content of K by shoot tissues of maize crop.

CONCLUSIONS

Hence it has been concluded from the previous findings of these studies that the conjunctive adoption of tillage operation and mulching might be encouraged by the farming community on a large scale basis to enhance the productivity to maize in order to feed the surging population of our country in existing arid environment conditions. Hence, this would be a paradox for policy makers to adopt such a scientific skill strictly to improve the productivity of existing cropping scheme in an arid agro-ecosystem. It has also been concluded from the findings that the conjunctive adoption of tillage operation and mulching has been developed into a viable option to enhance productivity of maize crop under arid agro ecosystem which would become helpful on a broader text in our agricultural policy system.

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APPENDICES

Table 1: Physical and Chemical Characteristics of Experimental Rate before Imposition of Treatments

Characteristics	Value
ECe (dSm^{-1})	1.41
pH	7.60
Organic matter (%)	0.22
No3-N (mg kg^{-1})	7.9
NaHCO3 extractable Phosphorus (mg kg-1)	7.62
NH4OAc- extractable Potassium (mg kg^{-1})	71.0
Saturation percentage	34.25
Hydraulic conductivity (X 10-4) [cm s^{-1}]	2.23
Bulk density (Mg m^{-3})	1.26
Textural Class	Sandy clay loam

Table 2: Effect of Different Tillage Operations and Mulching on Growth and Development of Maize Crop at Maturity

Tillage Operation	Mulch (Mg ha^{-1})				Mean
	0	2	4	6	
Plant Height (cm)					
Zero	1.25	1.29	1.29	1.32	1.29 a
Conventional	1.21	1.20	1.13	1.13	1.17 b
Deep	1.03	1.09	1.05	1.05	1.05 b
Mean	1.46 a	1.19 a	1.16 a	1.16 a	-
(b) Biological Yield (Mg ha^{-1})					
Zero	12.6	16.8	17.5	18.5	16.3c
Conventional	22.2	23.3	25.6	27.8	24.5b
Deep	22.0	26.5	32.1	34.5	28.8 a
Mean	18.9 b	22.2 b	25.1c	26.1 c	-

Note: Means followed by different letters are significantly different at 5% level.

Table 3: Effect of Different Tillage Operations and Mulching on Grain Weight and Yield of Maize Crop

Tillage Operation	Mulch (Mg ha^{-1})				Mean
	0	2	4	6	
1000- Grain Weight (g)					
Zero	578.5	726.3	736.1	761.6	700.6 b
Conventional	693.2	751.9	764.6	773.4	745.8 a
Deep	696.3	761.0	778.2	788.6	756.0 b
Mean	656.0 b	746.4 a	759.6 a	774.5 a	-
(b) Grain Yield (Mg ha^{-1})					
Zero	8.16	9.09	9.66	10.18	9.27 a
Conventional	8.73	9.57	9.92	10.62	9.71 a
Deep	10.23	10.48	11.20	11.57	10.87 b
Mean	9.04a	9.71b	10.26b	10.79b	-

Note: Means followed by different letters are significantly different at 5% level

Table 4: Effect of Different Tillage Operations and Mulching on Physical Characteristics of Soil after Harvesting of Maize Crop

Tillage Operations	Mulch (Mg ha-1)				Mean
	0	2	4	6	
Zero	1.25	1.29	1.29	1.32	1.29 a
Conventional	1.21	1.20	1.13	1.13	1.17 b
Deep	1.03	1.09	1.05	1.05	1.05 b
Mean	1.46 a	1.19 a	1.16 a	1.16 a	-
(b) Hydraulic Conductivity (X10^{-4}) [cm s^{-1}]					
Zero	2.23	2.29	2.46	2.48	2.36b
Conventional	2.96	3.10	3.10	3.13	3.07a
Deep	3.00	3.17	3.17	3.18	3.13a
Mean	2.73a	2.85a	2.91a	2.93a	-

Table 5: Effect of Different Tillage Operations and Mulching on Chemical Analysis of Soil after Harvesting of Maize Crop

Tillage Operations	Mulch (Mg ha^{-1})				Mean
	0	2	4	6	
(a) Organic Matter Content (%)					
Zero	0.22	0.52	0.55	063	0.48a

Table 5: Contd.,

Conventional	0.40	0.58	0.62	0.68	0.57a
Deep	0.40	0.49	0.60	0.64	0.53a
Mean	0.34a	0.53b	0.59c	0.65c	-
(b) Nitrogen Content (%)					
Zero	0.58	0.81	0.90	1.10	0.84a
Conventional	0.70	0.82	0.92	1.10	0.88a
Deep	0.79	0.98	1.00	1.12	0.98a
Mean	0.69c	0.87b	0.94a	1.10a	-
(c)Phosphorus Content (mg kg^{-1})					
Zero	7.67	11.53	11.75	12.17	10.78c
Conventional	8.77	12.61	12.86	12.90	11.66b
Deep	10.81	13.00	13.24	13.94	12.47a
Mean	9.08c	12.21b	12.61a	13.00a	-
(d) Potassium Content (mg kg^{-1})					
Zero	71.6	80.6	88.3	90.0	82.6a
Conventional	76.0	86.00	95.0	100.0	89.3a
Deep	86.6	92.6	100.3	106.0	94.9a
Mean	78.1a	86.4a	94.5a	98.7a	-

Note: Means followed by different letters are significantly different at 5% leve

Table 6: Effect of Different Tillage Operations and Mulching on Nutrients Concentrations in Shoot of Maize Crop at Maturity

Tillage Operations	Mulch (Mg ha^{-1})				Mean
	0	2	4	6	
(a) Nitrogen Concentration (%)					
Zero	1.50	1.56	1.60	1.63	1.58a
Conventional	1.52	1.58	1.60	1.64	1.58a
Deep	1.53	1.60	1.61	1.64	1.60a
Mean	1.52a	1.58a	1.61a	1.64a	-
(b)Phosphorus Content (mg Kg^{-1})					
Zero	0.08	0.09	0.10	0.11	0.10c
Conventional	0.08	0.12	0.12	0.13	0.11b
Deep	0.08	0.13	0.13	0.14	0.12a
Mean	0.08c	0.11b	0.12b	0.13a	-
(c) Potassium Content (%)					
Zero	2.36	2.40	2.43	2.43	2.41a
Conventional	2.40	2.43	2.43	2.44	2.42a
Deep	2.40	2.46	2.46	2.46	2.44a
Mean	2.39a	2.40a	2.44a	2.44a	-

Note: Means followed by different letters are significantly different at 5% level